Extreme Ultraviolet Frequency Combs for Spectroscopy

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Besides ongoing work to improve the spectral resolution of our hydrogen apparatus we plan to extend our investigations to hydrogen-like helium ions. The determination of hydrogen transition frequencies allowed for one of the most accurate tests of quantum electrodynamics (QED) and to improve the accuracy of the Rydberg constant. The advantage of charged particles is that they can be held in a trap and brought to rest by interaction with laser cooled co-stored ions of another type. Lacking the hyperfine interaction, $^4He^+$ is even simpler than hydrogen. The contributions of the nuclear charge radius to the theory, that has been limiting theoretical prediction, are better known for He^+ and more powerful methods exist to refine its measurement. Of central interest from the theoretical point of view is the scaling of QED terms with the nuclear charge Z. Currently the disputed terms are of the order Z^6 so that He^+ provides a far better test. The 1S-2S two-photon resonance of He^+ requires radiation at 61 nm. This could be generated as the 13th harmonic of a femtosecond ti:sapphire laser in a gas jet. So far, all experiments in high resolution laser spectroscopy were performed with spectrally narrow continuous wave lasers whose wavelengths reach down to the near ultraviolet. Lacking suitable continuous wave laser sources, the wavelength range beyond that, is almost completely unexplored for high resolution laser spectroscopy. If a coherent pulse train is used to generate the high harmonics, the resulting spectrum is not simply a broad continuum but has a regular array (frequency comb) of very sharp modes underneath it. These modes can be made spectrally narrow as in any other continuous wave laser and used for high resolution spectroscopy. We expect many more applications for the proposed method of spectroscopy and the extreme ultraviolet laser such as in lithography, xuv holography and Mößbauer type atomic clocks to emerge.